VCE Physical Education Units 3 and 4

Update of Content: Energy Systems

Introduction

Recent research and study of energy systems has led to a change in understanding within academic and sports training professions. This new knowledge also affects the understanding and application of training principles and methods. Knowledge of energy systems and related training principles and methods is an important aspect of coursework and the end-of-year examination.

Current undergraduates and recent graduates now have a contemporary understanding of energy systems that is inconsistent with that of most of the teaching profession. It is important that VCE students taught the latest understanding of energy systems are not disadvantaged in the end-of-year examination. To ensure that students completing VCE Physical Education Units 3 and 4 are not disadvantaged in using and being taught the latest understanding the following update on energy systems has been produced.

Whilst teachers are encouraged to use and teach the information supplied, students would not be penalised for using the current understanding correctly in the end of year examination for 2001.

The updated information specifically relates to:

VCE Physical Education Unit 3 Area of Study 1. Understanding fitness, includes knowledge of:

- energy systems- aerobic and anaerobic; and
- fitness training principles and methods.

In Unit 3 there are two outcomes, students must draw on key knowledge related to either/both bullet points to demonstrate Outcomes 1 and 2.

Energy Systems
Re-evaluating high intensity energy contributions

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Training for all sports and athletic endeavors focuses predominantly on developing physical skills and capacities that are specific to the unique demands of the sport. While it is generally well understood that energy is produced either anaerobically or aerobically, it is often misunderstood how these energy systems interact over time during high-intensity efforts. The energy for muscle contraction during exercise comes from the splitting of a high-energy compound called adenosine triphosphate (ATP). As soon as the small stores of ATP in muscles are partially depleted at the start of exercise then the ATP is replaced rapidly by the three energy systems working together but at different rates.

The first process involves the high-energy fuel phosphocreatine (PC) that is stored in small amounts in the muscles. The second process involves the non-aerobic breakdown of carbohydrate to lactic acid, and is often called the lactic acid system or anaerobic glycolysis. These two processes occur without the use of oxygen and together make up the anaerobic (without air) energy system.

The anaerobic system is capable of producing energy very rapidly and can result in large muscle power outputs during brief intense events such as in jumping and sprinting. It is limited, however, by the amount of energy it can produce. The build-up of lactic acid and a quick depletion of PC will bring about a reduction in power and a drop off in speed.

The aerobic energy system, on the other hand, is capable of producing extremely large amounts of energy. The down side is that it cannot produce energy as quickly, being limited by the muscle’s ability to breakdown carbohydrates and fats with the aid of oxygen, and the body’s ability to deliver the required oxygen to the working muscles.

Together, the three energy systems are well suited to cope with the high, often sustained, and usually diverse energy demands we place on them during our sporting exploits. For example, the PC system is very important for lifting, jumping, throwing, and short sprints. The lactic acid system is more suited to sustained sprints such as the 100 m, 200 m and 400 m, and the aerobic system to middle distance and endurance events. It is important to remember, however, that virtually all physical activities will derive some energy from each of the three energy systems.

The energy systems do not function like a set of lights switching from one to the other as the duration of exercise gets longer. The three energy systems are all turned on at the beginning of exercise. However, because the breakdown of PC to form ATP is a simple fast process, this energy store produces maximal power in the first few seconds of exercise and is fully dissipated in 10–20 seconds (see Figure 1). The more intense the exercise the faster it is used up. Also at the beginning of intense exercise anaerobic glycolysis is turned on with large amounts of lactic acid being produced in the first 10 seconds. Up to 40–45% of ATP can be produced from this energy source in a 100 m sprint. Peak anaerobic power from this energy source is generally reached in 5–15 seconds (see Figure 1).

Recent evidence from a number of laboratories around the world suggests that the aerobic system also turns on quickly during high intense exercise and plays a significant role in sprint and high-intensity endurance performances (see Figure 1). In cycling, for example, almost

50% of the energy required for a 60 second exhaustive effort comes from the aerobic system. After only 30 seconds of exercise, the oxygen uptake can be as high as 70–90% of the athlete's maximum aerobic power and very close to maximal power after a minute of intense exercise (see Figure 1).

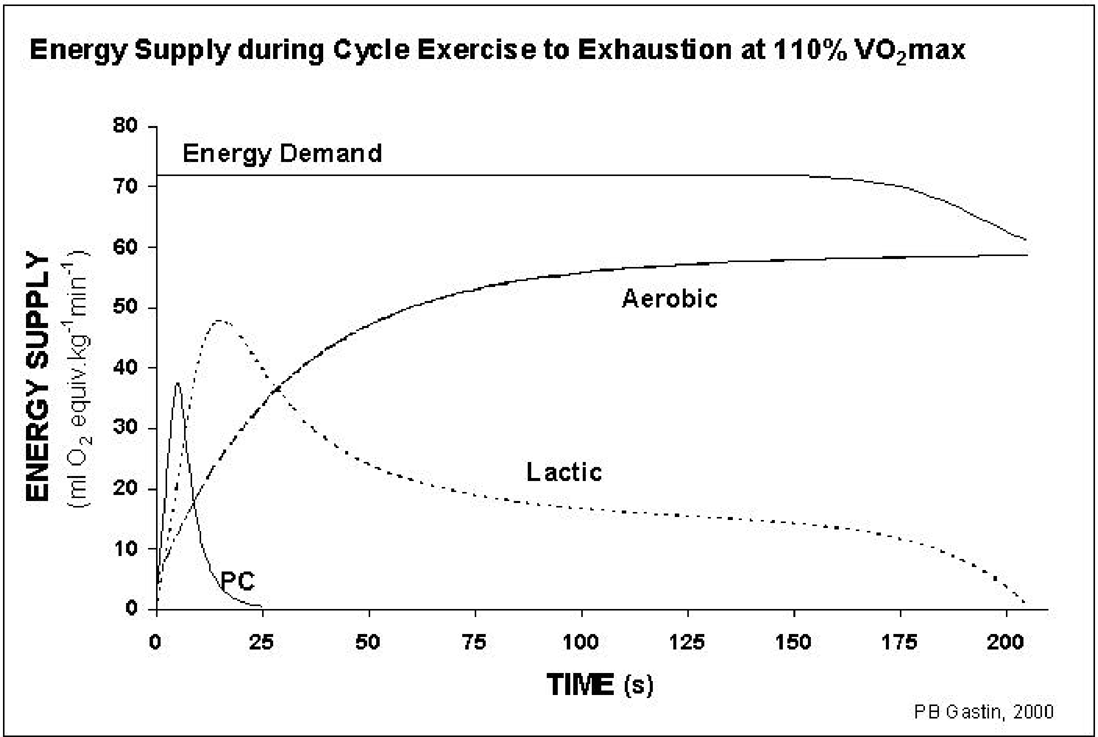


Figure 1: The three energy systems - high intensity exercise.

In an attempt to more closely measure the anaerobic and aerobic energy contributions to track running performances, two recent studies at the University of Ballarat measured VO_2 breath by breath at the mouth while running at race pace for 200 m, 400 m, 800 m and 1500 m on a custom-built treadmill. The oxygen uptake increases over time as illustrated by the black bars in Figure 2 for the 400 m, 800 m and 1500 m performances on the treadmill. The top graph represents a 50 second 400 m performance. The middle graph presents a two minute 800 m performance and the lower graph represents a four minute 1500 m performance. The oxygen cost for running at these speeds was estimated from a series of sub-maximal tests with a range of intensities below VO_2 peak. The VO_2 -speed relationship developed from these sub-maximal tests was used to estimate the oxygen cost of running at the higher speeds of the simulated performances. The difference between the estimated oxygen cost and the measured VO_2 is the oxygen deficit for that time interval and represents the anaerobic energy contribution. The addition of all the oxygen deficits for an exercise trial is called the accumulated oxygen deficit (AOD) and represents the anaerobic capacity of an individual. The AOD for the 400 m, 800 m and 1500 m track events is illustrated by the white bars in Figure 2.

The two studies detailed above and other studies completed by scientists over the last ten years using oxygen deficit and muscle biopsy techniques, have demonstrated the relative importance of the aerobic and anaerobic energy systems for maximal exercise between 5 and 240 seconds duration. Table 1 presents a compilation from a number of these studies of the relative aerobic contribution to maximal efforts of different durations. This table offers a reliable alternative to many tables and figures published in textbooks over the years. Most of these originated from the early calculations of Fox and colleagues who used the now discredited oxygen debt methodology to represent anaerobic energy release.

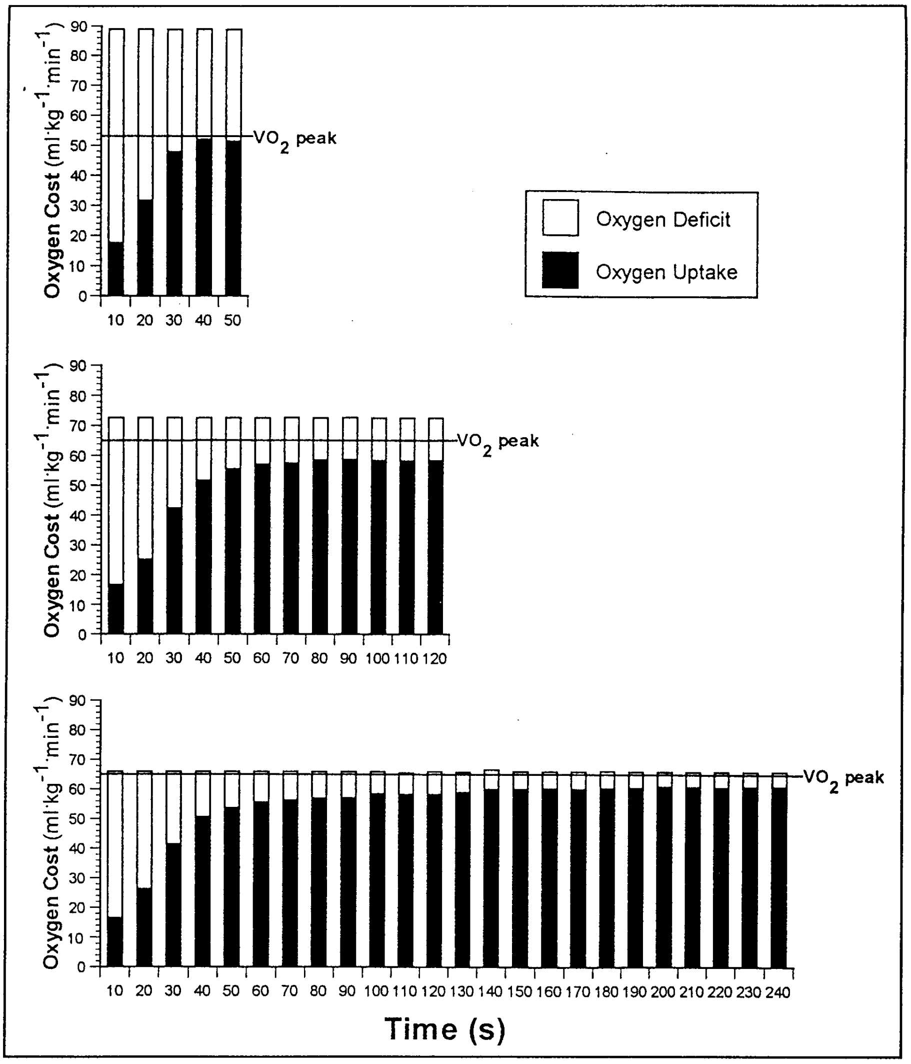
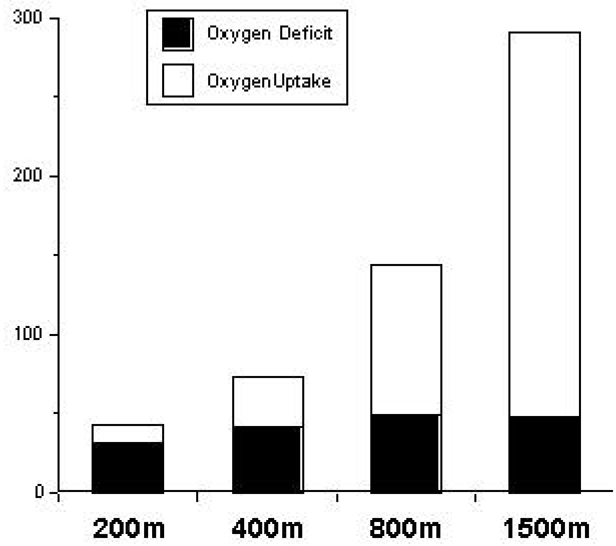


Figure 2: Oxygen uptake and oxygen deficit during simulated track running races (Spencer, Gastin & Payne, 1996)

Table 1: Relative contributions of Anaerobic and Aerobic Energy to maximal exercise of different durations

Duration of Exhaustive Exercise	**% Anaerobic**	**% Aerobic**
0 - 15 s	88	12
0 - 30 s	73	27
0 - 45 s	63	37
0 - 60 s	55	45
0 - 90 s	44	56
0 - 120 s	37	63
0 - 180 s	27	73
0 - 240 s	21	79

Data are from both trained and untrained individuals during either run, swim, bench or cycle ergometry exercise (Gastin, 2001).



Subject Number	3	6	6	6
Duration (min:sec)	22.3	49.3	1:53	3:55
Intensity (% VO_2max)	201	151	113	103
% Aerobic	29	43	66	84

Figure 3: Energy system contribution in track athletes during simulated running events on a treadmill (Spencer & Gastin, 2001)

Figure 3 depicts the energy demand for each of the four track events and the relative contribution of the aerobic and anaerobic systems to the energy supply. It is evident the amount of anaerobic energy release in the 400 m, 800 m and 1500 m events is quite similar. The difference between the events is the additional aerobic energy required for the longer duration performances. In the 400 m the anaerobic capacity is used up quickly, effectively enabling a high average speed to be maintained. In the 1500 m, the average speed is considerably less and the anaerobic capacity is used at a slower rate. The average speed is therefore determined by the size of the anaerobic capacity and the maximum rate that the aerobic system can deliver energy.

Effective training for the long sprint and middle distance events is a fine balance between developing both the aerobic and anaerobic energy systems. Too great an emphasis on either system will adversely affect the other. We do know that the anaerobic capacity is less trainable than the aerobic system. We also now know that the aerobic system plays a significant role in performances as short as 30 seconds in duration. Perhaps the best combination of training for these events is a well-developed aerobic system without a loss of speed. This can be achieved by quality efforts with long rests and few repetitions in conjunction with solid endurance training. It is also important to remember that maximum oxygen uptake can be effectively trained using interval methods. The significant contribution of the aerobic system during the high intensity efforts in the research presented here supports this notion. Too great an emphasis, however, on lactate tolerance training will have an adverse effect on the aerobic system. Getting the balance right is the main objective.

In summary, the production of ATP energy during high-intensity exercise relies on the three energy systems working together. The phosphocreatine energy system produces energy at the fastest rate in the first 5 seconds of exercise. Anaerobic glycolysis produces energy at the fastest rate from the time when the PC system is rapidly depleting up until about 25–30 seconds, after which the aerobic system supplies energy at the fastest rate. However, when the overall relative energy system contribution is calculated for exercise efforts lasting set time intervals, the anaerobic energy systems supply the greater proportion of the required energy for all maximal exercise efforts up to 75 seconds in duration. This may differ for efforts that are less than maximal, yet over similar durations.

References

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